Collimation

General Considerations.--Surface measurement devices generally consist of two major types: (1) those that use monuments and markers or targets to measure movements of the dam from a remote point, and (2) those that are mounted on the exterior or interior surfaces of the dam from which differential movements of portions of the structure are determined, including measurements at joints or cracks. The devices are used to measure total or relative horizontal, vertical, or rotational movements or differential movements in any desired plane. Examples of systems using monuments and markers are collimation (tangent-line measurements), levels, trilateration and triangulation, and the more common surveying angle-distance closure systems. These techniques are discussed in the following sections.

Collimation Measurements.—

a. General.--Collimation or tangent-line measurements are a means for determining the deformation of a concrete dam with respect to references located off the dam. The bending, tilting, or horizontal displacement of a concrete dam may usually be detected by accurately measuring changes in the horizontal position of the various portions of the dam. Measurements of the location of dam monoliths at regular intervals over several years provide an indication of the magnitude of deformations that occur in the structure, its foundation, and abutments.

b. Advantages and Limitations.--These methods provide information on the magnitude and direction of movements of a dam with reference to the dam's surroundings, not merely relative movement of points on the dam. The surveying methods used are relatively common techniques; however, they must be performed to a high degree of accuracy to provide meaningful information. Instrument piers and targets located off the dam must be constructed so that they will not move and thereby destroy the accuracy of the measurements on the dam.

c. Description of Devices.--The instruments and devices used for collimation measurements include theodolites, stationary instrument piers and plates, moveable and fixed targets, and embedded markers or plugs.

(1) Precision Surveying Equipment.--All surveying readings are taken with highly precise surveying equipment. Care should be taken to achieve precise and accurate data when using theodolite equipment.

(2) Instrument Piers and Targets.--Instrument piers are located on one of the abutments at a concrete dam, usually the one that has the easiest access for instrument setup, and should be rounded on solid rock when possible. Depending upon the curvature of an arch dam and the number of points to be monitored on the crest, more than one pier may be required.
On the opposite abutment, sighting targets are installed at as many locations as required to accommodate the moveable targets located at the measurement points on the dam. These sighting targets are installed in 1.5-inch diameter pipes that have been solidly cemented into holes drilled into the abutment.

(3) Moveable Targets and Plates.--The moveable targets, which fit on plates affixed to the dam. The plates are common to the fixed piers and the dam targets. The three 120° V-slots in the anchor plate ensure correct alignment. Measurements must consistently be taken from the same fixture post to the moveable wheel.

d. Installation Procedures.--As previously discussed, instrument piers installed on the abutment may be constructed during or after construction of the dam. However, it is essential that these monuments do not change position; therefore, they are constructed of concrete securely anchored in place below frost depth. For locations on top of the dam, target plates are installed after construction has been completed. These plates are installed by drilling three holes at the proper location and grouting the anchor bolts and plates in place. Consideration should be given to the reservoir water load, season of the year, and the amount of heat remaining in the structure when locating the position of the plates so that subsequent deformation of the structure will not exceed the range or limit of movement of any collimation target.

e. Monitoring Procedures.--The measurements are made using first-order equipment, methods, and procedures insofar as feasible. The results of the measurements show deformation of a dam with respect to off-dam references. When measuring to the moveable target wheel, the wheel should be moved in the same direction each time so that any slack in the wheel will always be accounted for.

f. Maintenance.--Maintenance of collimation systems involves keeping the measurement points clear and visible from the necessary reference lines and points. Normal maintenance of the surveying equipment is also required.